Recent Progress in Development of Hydrogen Sorption Cryocoolers for Space Applications

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Sorption cryocoolers consist of a sorption compressor that contains appropriate sorbent material and a Joule-Thomson (J-T) expander. Hydrogen is the refrigerant selected for cooling in the temperature range from 30 K down to ~8 K. Metal hydride sorbent beds provide the closed-cycle circulation of hydrogen through heat exchangers and the J-T valve. Sorption coolers are uniquely suited for cooling detectors in several planned astrophysics missions. These missions impose challenging cooler requirements including ten year life, zero vibration, zero EMI/EMC operation and the ability to scale designs to provide a few milliwatts of refrigeration while consuming only a few watts of input power.

The current status in the development of hydrogen sorption cryocoolers is described in this paper. Results from both ground test and a Shuttle spaceflight are summarized for the BETSCE 10 K sorption cryocooler that formed solid hydrogen during intermittent operation with quick cooldown capability. This experiment provided flight characterization of all sorption cryocooler design parameters that could be impacted by microgravity effects. Post-flight ground tests showed no indications of microgravity induced changes to either sorbent bed or J-T expander performance. A continuous-operation 25 K sorption cryocooler producing liquid hydrogen in the J-T reservoir has been built and is now in final integration and performance testing. This cooler was developed for use in a long duration airborne balloon experiment during measurement of cosmic microwave background anisotropy and will be the first hydride sorption cooler to support an astrophysics experiment. Ground test results obtained with this cooler will be presented. The design and performance predictions for an improved hydride sorbent bed for 20 K coolers with the potential to achieve 10 years of continuous operation with minimal degradation will be reported. These beds are currently in fabrication and will be subjected to extended thermal cycling tests to assess their performance. Finally, the conceptual design for continuous 20 K sorption cryocooler to provide cooling to instruments in the proposed Planck Surveyor astrophysics mission will be described. This single-stage cooler presumes a 50 K telescope enclosure and precooling temperature for the J-T coldhead. In this configuration, the nominal performance for the cooler is a 1.2 W heat load at 18 – 20 K with 360 W of input power. The proposed integration of the hydrogen sorption cryocooler to the Planck instruments and a 4 K closed-cycle helium J-T cryocooler will be outlined.